MULTI-CRITERIA LOCATION ANALYSIS FOR EMERGENCY DISTRIBUTION CENTER IN PREFLOOD OF KANTO DISTRICT

Yufeng GUO[1], Takuma MATSUDA[2] and Etsuko NISHIMURA[3]

[1] Student Member of JSCE, Graduate School of Maritime Sciences, Kobe University
(5-1-1 Fukae-minami, Higashinada, Kobe 658-0022, Japan)
E-mail: 219w701w@stu.kobe-u.ac.jp (Corresponding Author)
[2] Member of JSCE, Professor, Faculty of Commerce, Takushoku University,
(3-4-14, Kohinata, Bunkyo-ku, Tokyo 112-8585, Japan)
E-mail: tmatsuda@ner.takushoku-u.ac.jp
[3] Member of JSCE, Professor, Graduate School of Maritime Sciences, Kobe University
(5-1-1 Fukae-minami, Higashinada, Kobe 658-0022, Japan)
E-mail: e-nisi@maritime.kobe-u.ac.jp

Natural disasters occur fluently worldwild, resulting enourmous human casualties, environmental damage and property losses. The selection of distribution centers (DCs) is a crucial task because it impacts the operational efficiency of disaster logistics management. Therefore, this study focuses on selecting (DCs) in the pre-disaster period based on the case of a flood in the Kanto district of Japan using the MCDM method. The purpose of this study was to rank existing private DCs and evaluate their location tendency and utilization. The Analytic Hierarchy Process (AHP) was applied to determine weights of eight criteria: floor area, build-up floor, population density, depth of flood inundation, distance to the nearest highway, airport and port, and land cost. Weighted Aggregated Sum Product Assessment (WASPAS) is used to calculate DCs' score and rank them. And *k*-means is applied to classify DCs to evaluate the DCs' location tendency. The results show that the top-ranked DCs are located in Saitama. Furthermore, DCs located along the Ken-O express are ranked relatively higher in the same region.

Key Words : *disaster logistics, distribution center, flood, selection, MCDM*

1. INTRODUCTION

Natural disasters such as earthquakes, tsunami, floods, storms and wildfires occur fluently worldwild, resulting human casualties, environmental damage, and property losses (Rimadeni et al., 2021,). For example, In 2021, Haiti's magnitude 7.2 earthquake Haiti caused a large number of casualties and house collapse, it was the worst disaster to strike Haiti since the 2010 earthquake. The flash flood that happened in India in 2021 also caused massive loss of farm animals, agricultural land, property, and infrastructure (Rautela et al., 2022). Japan is one of the most disaster-prone countries in the world. The Great East Japan Earthquake in 2011 (Suzuki and Kim, 2012) and the Kumamoto Earthquake in 2016 also caused a lot of human and physical damage. In addition, in 2019, Typhoon No.19, brought about record-breaking rainfall across East Japan from 12 to 13 October 2019, and it caused widespread flooding in many regions including Tokyo, Chiba and Nagano prefectures, a large number of residents who lived in Kanagawa, Tokyo, Saitama and Chiba were urged to evacuate (Fang and Huang, 2020).

With disaster occurring frequently around the world, disaster logistics is one of the active fields that has got much attention in Operations Research and Management Science (Li, Zhang and Ge, 2022), which involve planning, managing, and controlling the flow of resources to provide relief to the people affected (Caunhye et al., 2016). Logistics managenment is one of the essential tasks in disaster management, which contains planning and inventorying needs, procurement and reception, warehousing and storage, distribution, transportation, receiving to destination, elimination and accountability (Rimadeni et al., 2021). Where to locate warehouses is a significant mission for the operation of disaster logistics management because it stores relief supplies and is the transit node for distribution which can affect the capacity of providing aid and rescue plan (Mittal and Obaid, 2023). Loree and Aros-Vera (2021) stated that the location of points of distribution can be determined through using a mathematical model in post-disasters. It can be seen that the location of DCs play a critical role in disaster logistics management. To improve the operational efficiency of disaster logistics management, it is also important to select and utilize the existing DCs.

Therefore, this study aims to select and rank the wide-area DCs and evaluate the location tendency for higher and lower-ranked DCs based on the combination of AHP-WASPAS-*k*-means.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 presents the theoretical methods and their applications. Section 4 presents the case study results. Section 5 summarizes the discussions and conclusions and highlights future research.

2. LITERATURE REVIEW

(1) Literature on the location problems of emergency logistics

Emergency distribution centers, as the primary component of emergency logistics facility, plays a crucial role in post-disaster emergency management for distributing relief supplies (Wan, Chen and Dong, 2021; Wang and Ma, 2021), such as water, food, and medicine for emergency rescue were prepared and stocked. Location decision of DCs for the prepositioning of supplies to support treatment centers in the delivery of care to those affected by a disaster is a multifaceted problem (Paul and Donald, 2016).

Therefore, the emergency distributions problem has received great attention from more and more scholars. Tofighi, Torabi and Mansouri (2016) addressed a two-echelon humanitarian logistics 17 network design problem involves multiple central warehouses and local DCs. Balcik and Beamon (2008) developed a model that determines the number and locations of DCs to meet the demand of people who were affected by disasters. Rawls and Turnquist (2010) proposed an emergency response planning tool that determines the location and quantities of various types of emergency supplies to be pre-positioned, under uncertainty about if, or where, a natural disaster will occur. Paul and Hariharan (2012) developed a model to determine the locations and capacities of stockpile sites that are optimal for a specific disaster. This model considers the impact disaster specific casualty characteristics, such as the severity and type of medical condition and the unique nature of each type of disaster.

In addition, there are many multi-criteria decision making (MCDM) approaches for selecting DC locations. For example, Mittal and Obaid (2023) used Best-Worst and Technique for Order Performance by Similarity to the Ideal Solution (TOPSIS) to determine the ideal warehouse site for making make humanitarian networks more accountable. Guo and Matsuda (2023) applied MCDM method to select location of DCs based on a case of earthquake in the Kanto district of Japan.

According to the literature, it can be concluded that the mathematical model, MCDM approach, and fuzzy logic, are basically to be proposed for the selection of DC location. And the study position is shown in **Table.1**.

Table 1 Study position

Method	**Mathematical model**	**MCDM approach**	**Fuzzy logic**
Pre-disaster		This study	
Post disaster			

(2) Literature on the Application of AHP

Many scholars have used AHP to solve the MCDM problem. For example, Polat (2018) use AHP to select the type of case for raw material to be placed in by the supplier. The Vehicle Routing Problem (VRP) is an important operational decision in the distribution network and has a significant role in cost reduction and service improvement which facilitates the routing and scheduling of deliveries. Balaji, Santhanakrishnan and Dinesh (2018) proposed an effective hybrid approach that combines customer prioritization with Clarke and Wright's savings algorithm to solve the capacitated vehicle routing problem. Routing policy selection is a multi-criteria and multi-decision problem, Tuhamy, Elatif and El-Bakry (2016) used the AHP method to select the optimal routing policy which appropriates the performance measures and system objectives. Kieu et al.,(2021) proposed a hybrid model for selecting a location distribution center through Spherical Fuzzy Analytic Hierarchy Process (SF-AHP) and Combined Compromise Solution (CoCoSo) Algorithm. Nong (2021) stated that AHP is one of the most popular methods for decision-makers to solve MCDM problems.

(3) Literature on the application of WASPAS

To survive in the global competitive environment, it now becomes more important for manufacturing organizations to take prompt and correct decisions regarding the effective use of their scarce resources. Chakraborty and Zavadskas (2014) used WASPAS to solve eight manufacturing decision making problems, such as selection of cutting fluid, electroplating system, forging condition, arc welding process, industrial robot, milling condition, machinability of materials, and electro-discharge micro-machining process parameters. To select a flexible manufacturing system, a machine in a flexible manufacturing cell, 25 automated guided vehicles, an automated inspection system, and an industrial robot for the manufactory, Chakraborty, Zavadskas and Antucheviciene (2015) proposed a quite acceptable result using the WASPAS. Lukic et al. (2021) analyzed the efficiency of agricultural enterprises in Serbia based on WASPAS method. With the change of environmental criteria, the focus on risks and uncertain events is one of the essential goals of any organization, Badalpura and Nurbakhsh (2019) suggested WASPAS as a suitable method with more accuracy among MCDM techniques for evaluating risks of road construction project in Iran. Rudnik et al. (2020) proposed an ordered fuzzy WASPAS method for selecting improvement projects. The advantage of the proposed method is its ability to provide project assessments in the form of fuzzy numbers or qualitative assessments together with the description of the likely direction of assessment change in the nearest future. In maintaining the quality of its employees' performance, Utami and Ruskan (2019) suggested the Public Works Department of Highways and Spatial Planning of South Sumatra Province evaluate performance using WASPAS regularly.

3. METHODOLOGIES

In this study, we applied MCDM methods named AHP and WASPAS to determine weights of criteria and rank DCs. Then we classify DCs by using *k*-means for evaluating location tendency of DCs. The overview of methodologies is illustrated in **Fig.2.**

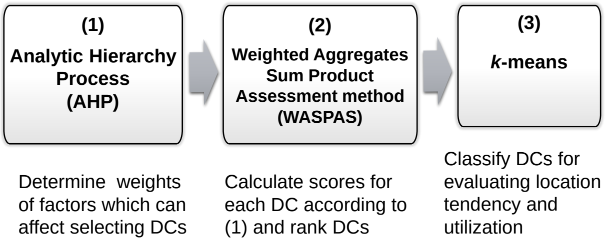


Fig.2 Overview of research methodologies

Table 3 Values of a random consistency index (*RI*)

M	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

(1) AHP

AHP is an MCDM method for organizing and analyzing complex decisions through pairwise comparisons. the theory of AHP will be briefly reviewed, which includes the following steps.

First, we construct an $m \times m$ pairwise comparison matrix.

$$\mathrm{A} = \begin{pmatrix} a_{11} & a_{12} \cdots & a_{1m} \\ a_{21} & a_{22} \cdots & a_{2m} \\ \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} \cdots & a_{mm} \end{pmatrix} \tag{1}$$

Second, we normalize the rows of the pairwise comparison matrix by geometric means.

$$r_i = \sqrt[m]{\prod\nolimits_{j=1}^{m} a_{ij}} \tag{2}$$

where r_i is the *m*-th degree root of the *i*-th row, *i* indicates the number of rows belonging to 1, 2, …, *m*, and *j* is the number of columns belonging to 1, 2, …, m.

Third, we calculate the weighting of the criteria and largest eigenvalue using (3) and (4):

$$\omega_i = \frac{r_i}{\sum_{i=1}^{m} r_i} = \frac{\sqrt[m]{\prod_{j=1}^{m} a_{ij}}}{\sum_{i=1}^{m} \sqrt[m]{\prod_{j=1}^{m} a_{ij}}} \tag{3}$$

$$\mathrm{A}\boldsymbol{\omega} = \lambda_{max}\boldsymbol{\omega} \tag{4}$$

Fourth, we must check the consistency ratio (*CR*) by comparing it with the randomly generated consistency index using (3) and (4).

$$CI = \frac{\lambda_{max} - m}{m - 1} \tag{5}$$

$$CR = \frac{CI}{RI} \tag{6}$$

where *m* is the order of matrix A, and the random consistency index (*RI*) is given in **Table 3**, which shows the order of the matrix and the corresponding value of *RI* . If *CR* < 0.1, the matrix is consistent, and the experts' estimates agree.

(2) WASPAS

The WASPAS method is typically applied in the following steps:

First, we determine the optimal value for each criterion using (7).

$$x_0 = \begin{cases} \max x_{ij} & j \in c_{max} \\ \min x_{ij} & j \in c_{min} \end{cases} \tag{7}$$

where x_0 is the optimal performance value of the *j*-th criterion, max x_{ij} is the maximum of *i*-th alternative to the j-th criterion, and $\min x_{ij}$ is the minimum of i-th alternative to the j-th criterion; c_{max} shows the beneficial criteria, which means the bigger the value, the better, c_{min} shows the cost criteria, which means that the smaller the value, the better; i indicates the number of alternatives (DCs) belonging to 1, 2, …, m; and j indicates the number of criteria belonging to 1, 2, …, n.

Second, we normalize the decision matrix of alternatives using (8).

$$x_{ij}^{*}=\begin{cases}1+\dfrac{x_{ij}-\min x_{ij}}{\max x_{ij}-\min x_{ij}} & j\in c_{max}\\[2ex] 1+\dfrac{\max x_{ij}-x_{ij}}{\max x_{ij}-\min x_{ij}} & j\in c_{min}\end{cases} \tag{8}$$

where x_{ij}^{*} is the normalized optimal value of the i-th alternative to the j-th criterion.

Third, we calculated the relative importance based on the WS and WP methods using (9) and (10).

$$Q_i^1=\sum_{j=1}^{n} w_j r_{ij} \tag{9}$$

$$Q_i^2=\prod_{j=1}^{n} {r_{ij}}^{w_j} \tag{10}$$

Finally, we calculate the total importance of each alternative using (11).

$$Q_i=\lambda Q_i^1+(1-\lambda)Q_i^2 \tag{11}$$

where λ is a coefficient that belongs to $[0,1]$, if decision-makers do not have preferences over the coefficient; in the usual case, the value is 0.5.

(3) *k*-means

In this study, k-means method is used to classify clusters for DCs as shown in (12), and elbow method is typically used to determine the optimal k.

$$L=\sum\nolimits_{i=1}^{N}\sum\nolimits_{j=1}^{k} r_{ij}\left\|x_i-u_j\right\|^2 \tag{12}$$

$$A_i^{*}=\frac{A_i-min\{A_j\}}{max\{A_j\}-min\{A_j\}} \tag{13}$$

where N is the number of data points, k is the number of clusters, x_i denotes the i-th data point, u_j denotes the center of the j-th cluster, r_{ij} indicates that if x_i belongs to u_j, it is 1; otherwise, it is 0. A_i^{*} is the normalized data of alternatives, A_i is the original data of alternatives, $\min\{A_j\}$ indicates the minimum value of *the* j-th criterion, $\max\{A_j\}$ indicates the maximum value of *the* j-th criterion, i belongs to 1, 2, …, n, and j belongs to 1, 2, …, n.

4. CASE STUDY

This study analyses the case of floods in the Kanto district of Japan, which contains Tokyo, Kanagawa, Chiba, Saitama, Ibaraki, Tochigi, and Gunma. The subject of this analysis are DCs located in the Kanto district. **Fig.4** shows the geographical location of Kanto district in Japan.

(1) Weights of criterion

In this study, the weights were judged by two logistics experts from the Logistics Policy Department of the Ministry of Land, Infrastructure, Transport, and Tourism, and the results is shown in **Table.5**. Positive criterion means the larger the value the better. Negative criterion means the smaller the value the better.

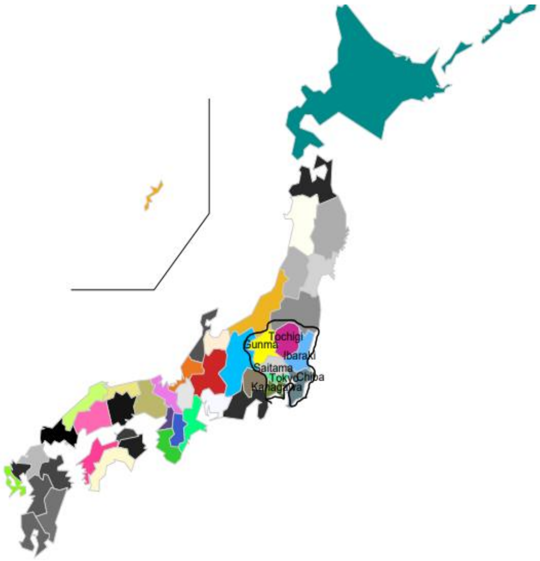


Fig.4 Map of the Kanto district of Japan

Table.5 Weights of criteria

Criteria	Weight	Rank	Type
Distance to the nearest highway	0.249	1	Negative
Floor area	0.232	2	Positive
Built-up area	0.232	2	Positive
Depth of flood inundation	0.102	4	Positive
Population density	0.083	5	Positive
Distance to the nearest airport	0.041	6	Negative
Land cost	0.040	7	Negative
Distance to the nearest port	0.022	8	Negative
CR = 0.07 (< 0.10)			

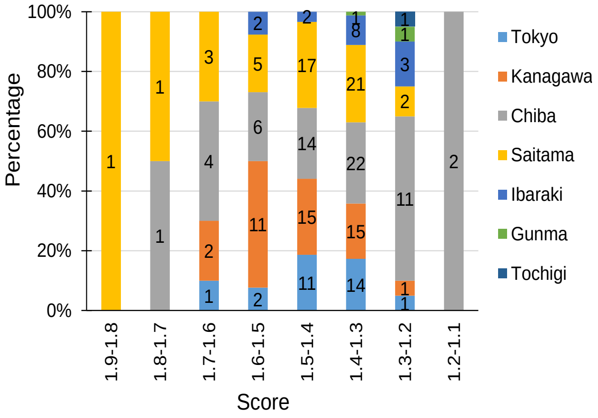


Fig.6 Percentage of DCs in each score range

(2) Scores and ranking of DCs

Scores and rankings of DCs were performed by WASPAS method which combines WS and WP method, and the results are shown in **Fig.6**. It can be found that scores of DCs located in Saitama are relatively higher than in other regions.

(3) Clusters of DCs

DCs are classified to six clusters by *k*-means, as shown in **Fig.7**. Moreover, before utilizing *k*-means, this study uses the elbow method to determine the optimal number of *k*.

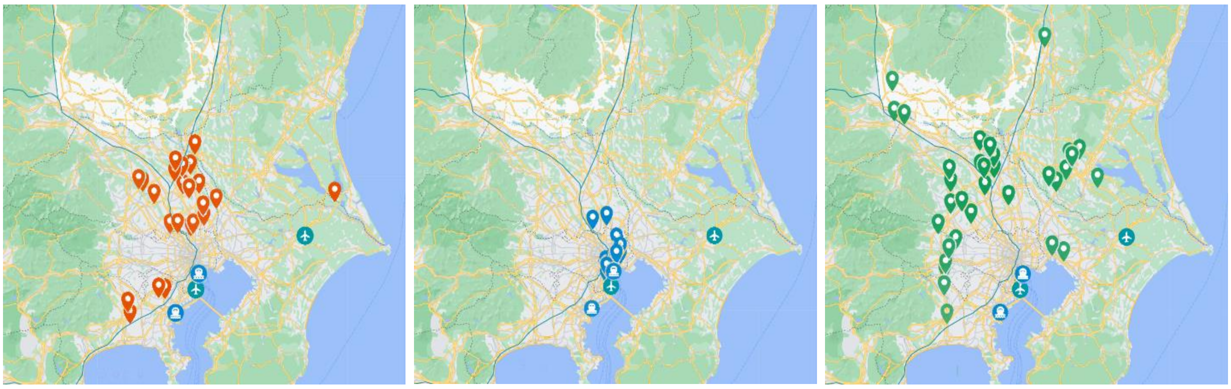
The 1st cluster (**Fig.7 (a)**) contains 36 DCs, and most of them belong to Saitama. From the results of WASPAS, it can be found that the ranking of DCs located in Saitama is relatively higher than that of DCs located in Kanagawa, Chiba and Ibaraki.

Fig.7 (b) presents the 2nd cluster which contains 17 DCs, all of which belong to Tokyo, and these DCs tend to the Haneda International Airport and the Port of Tokyo.

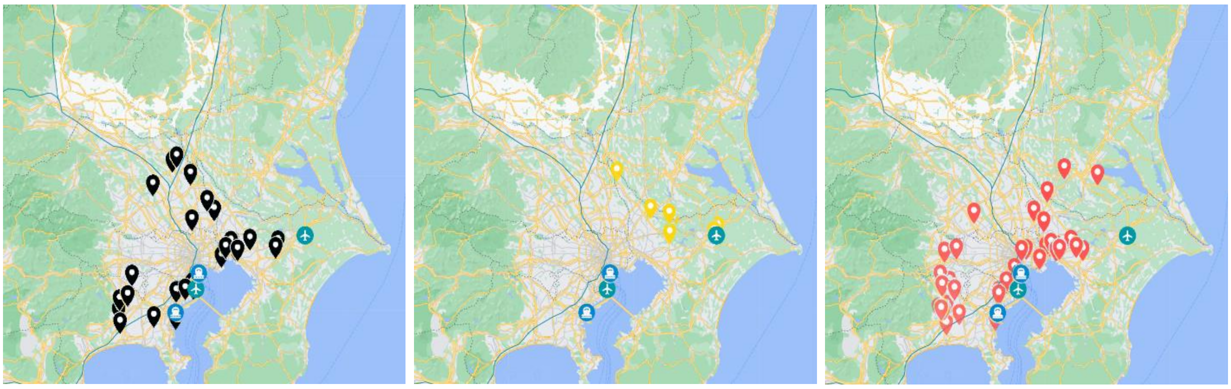
Fig.7 (c) shows the 3rd cluster which contains 46 DCs, most of which are located along the Ken-O express, and the ranking of DCs near Saitama is relatively higher than that in other regions.

Fig.7 (d) shows the 4th cluster which contains 27 DCs, and the highly ranked DCs belong to this cluster. It can be seen that DCs belonging to Kanagawa are near Ken-O express or tend toward Haneda International Airport and port, and DCs located in Chiba tend toward the Port of Tokyo.

Fig.7 (e) displays the 5th cluster containing 17 DCs located in Chiba and compares them to DCs located in Chiba in **Fig.7(d)**, the rankings of DCs are lower based on the results of WASPAS. In addition. DCs in this cluster tend to be far from airports and ports.



(a) 1st cluster (b) 2nd cluster (c) 3rd cluster



(d) 4th cluster (e) 5th cluster (f) 6th cluster

Fig. 7 DC clusters classified by k-means

Fig.7 (f) contains 58 DCs in the 6th cluster, and it can be seen that most of which are located along the Ken-O express or tend toward Haneda International Airport and port. Moreover, according to the ranking, DCs located along the Ken-O express are ranked higher than that in other areas.

5. DISCUSSIONS AND CONCLUSIONS

In this study, we applied the MCDM method, AHP and WASPAS to determine the weights of criteria that affect the selection DCs and determine the ranking of DCs in the pre-flood period. In addition, we evaluated the location tendency for six clusters classified using *k*-means.

From the ranking of DCs, it can be seen that higher-ranked DCs were concentrated in Saitama. Moreover, DCs located along the Ken-O express were ranked higher in the same region.

In addition, we also utilized this study in the case of an earthquake in the Kanto district of Japan, and it was found that the ranking of DCs would change, therefore, the priority of consideration and utilization of DCs are varies for different types of disasters.

One of our future tasks is to add some constraints, such as transportation time, cargo carrying capacity, and storage capacity of the DCs. Then, the MCDM method should be combined with the optimization method for analysis.

ACKNOWLEDGMENTS: This study was supported by JSPS KAKENHI Grant Numbers 20K22129 and 22K13501.

APPENDIX: Score and rank of DCs

DC	Score	Rank
Landport Kasukabe	1.8074	1
DPL Kawaguchi Ryoke	1.7612	2
DPL Chiba Yotsukaido	1.7508	3
DPL Misato II	1.6709	4
Logicross Funabashi	1.6510	5
Sakura D.C.	1.6361	6
Ichikawa D.C.	1.6322	7
Prologis Park Narashino 5	1.6274	8
SGH Residence Shinsuna	1.6270	9
MFLP Hiratsuka	1.6240	10
Prologis Park Soka	1.6180	11
SG Realty Kuki II	1.6020	12
DPL Shin Yokohama I	1.6010	13
Logiport Kawasaki Bay	1.5972	14
DPL Urayasu III	1.5850	15
Yokohama Sachiura D.C.1	1.5697	16
Prologis Park Koga 1	1.5683	17
LOGI'Q Sayama Hidaka	1.5669	18
DPL Isehara	1.5635	19
Prologis Urban Tokyo Adachi 2	1.5584	20
DPL Nagareyama III	1.5553	21
Hasuda II L.C.	1.5534	22
Prologis Park Narashino 4	1.5522	23
Prologis Park Koga 2	1.5521	24
Logiport Hashimoto	1.5478	25
DPL Nagareyama IV	1.5434	26
SG Realty Yokohama	1.5390	27
Prologis Park Narashino 3	1.5386	28
DPL Yokohama Totsuka	1.5373	29
MFLP Ichikawa Shiohama II	1.5335	30
Kawasaki Yako D.C.	1.5298	31
Kawaguchi L.C. B	1.5268	32
Sagamihara Onodai L.C.	1.5259	33
Prologis Park Yokohama Tsurumi	1.5228	34
Kawasaki Ukishima D.C.	1.5147	35
Kawaguchi Ryoke L.C.	1.5077	36
Kawagoe D.C. A	1.5068	37
SG Realty Shin-Kiba P	1.5032	38
Prologis Park Ebina 2	1.5005	39
SG Realty Higashi-Matsuyama	1.4983	40
Landport Atsugi	1.4975	41
LOGI'Q Kashiwa	1.4975	42
Prologis Park Ebina	1.4969	43
Logicross Atsugi	1.4942	44
Landport Itabashi	1.4941	45
MFLP Atsugi	1.4929	46
LOGI'Q Narashino	1.4865	47
MFLP Tachikawa Tachihi	1.4838	48
LOGIBASE Shin-Sayama	1.4821	49
Logicross Ebina	1.4803	50
DPL Misato	1.4771	51
Yokohama Sachiura D.C. 2	1.4680	52
SG Realty Katsushima	1.4672	53
Kazo D.C.	1.4653	54
Prologis Urban Tokyo Oshiage 1	1.4640	55
T-LOGI Kuki	1.4596	56
MFLP Funabashi I	1.4523	57
LOGIBASE Itabashi	1.4501	58
MFLP Kuki	1.4497	59
Sagamihara Tana L.C.	1.4480	60
Landport Hachioji	1.4472	61
DPL Kawasaki Yako	1.4466	62
Prologis Park Kawajima 2	1.4446	63
Prologis Park Narita 1-C	1.4446	64
SG Realty Kashiwa, Building A	1.4438	65
Logicross Hasuda	1.4432	66
Atsugi Logistics and D.C.	1.4407	67
Atsugi Nairiku L.C.	1.4365	68
Prologis Park Tsukuba 2	1.4353	69
Hanyu L.C.	1.4335	70
SG Realty Wako	1.4332	71
MFLP Funabashi III	1.4330	72
DL Prologis Park Tokyo Shinagawa	1.4326	73
Landport Ome I	1.4300	74
Namamugi D.C.	1.4300	75
Chiba North D.C.	1.4295	76
MFLP Kawaguchi I	1.4294	77
DPL Urayasu IV	1.4294	78
DPL Shin Narashino	1.4279	79
Logicross Kasukabe	1.4278	80
MFLP Yokohama Daikoku	1.4274	81
Prologis Park Narita 1-A	1.4256	82

Landport Higashi Narashino	1.4239	83
MFLP Hiratsuka II	1.4230	84
Prologis Park Chiba 2	1.4229	85
SGH Residence Higashisuna	1.4208	86
CPD Matsudo I	1.4186	87
Kawaguchi L.C. A	1.4170	88
DPL Misato III	1.4137	89
DPL Saitama Kamisato B	1.4128	90
X Frontier	1.4125	91
DPL Sakato	1.4072	92
Logicross Yokohama Kohoku	1.4065	93
DPL National Fuchu	1.4057	94
Chigasaki D.C.	1.4034	95
MFLP Funabashi II	1.4023	96
Kawagoe D.C. B	1.4006	97
Prologis Park Tsukuba 3	1.4004	98
LOGI'Q Wangan Narashino	1.3987	99
GLP・MFLP Ichikawa Shiohama	1.3981	100
Prologis Park Tokyo Shin-Kiba	1.3977	101
DPL Tsukuba Ami I-A	1.3967	102
Toda D.C.	1.3962	103
Landport Ageo I	1.3953	104
DPL Tsukuba Ami II	1.3940	105
LOGI'Q Miyoshi	1.3938	106
Prologis Park Kawajima	1.3911	107
LOGI'Q Minamisunamachi	1.3903	108
Iwatsuki L.C.	1.3870	109
Prologis Park Tsukuba 1(A/B)	1.3865	110
MFLP Kashiwa	1.3865	111
MFIP Haneda	1.3862	112
DPL Soka	1.3847	113
Logicross Zama Komatsubara	1.3815	114
Landport Iwatsuki	1.3803	115
LOGIBASE Ichikawa	1.3803	116
Landport Kawaguchi	1.3800	117
MFLP Prologis Park Kawagoe	1.3796	118
Landport Niiza	1.3786	119
DPL Satte	1.3784	120
MFLP Yashio	1.3776	121
Prologis Park Koga 3	1.3768	122
MFLP Yokohama Kohoku	1.3737	123
Prologis Park Chiba 1	1.3724	124
LOGI'Q Shiraoka	1.3722	125
DPL Sagamihara	1.3705	126
Prologis Park Ichikawa 3	1.3703	127
DPL Nagareyama I	1.3697	128
DPL Kuki Miyashiro	1.3683	129
Prologis Urban Tokyo Shinagawa 1	1.3682	130
Prologis Park Ichikawa 1	1.3681	131
Kawajima D.C.	1.3638	132
Baraki D.C. 2	1.3636	133
MFLP Hino	1.3631	134
Urayasu Chidori D.C.	1.3623	135
Landport Koshigaya	1.3593	136
MFLP Atsugi II	1.3589	137
DPL Hiratsuka	1.3587	138
MFLP Funabashi Nishiura	1.3584	139
Landport Urayasu	1.3580	140
Baraki D.C. 1	1.3572	141
CPD Matsudo II	1.3555	142
Landport Hachioji II	1.3555	143
Prologis Park Zama 1	1.3551	144
MFLP Tsukuba	1.3519	145
SG Realty Matsuzakidai	1.3515	146
Prologis Park Ichikawa 2	1.3510	147
MFLP Kawasaki I	1.3507	148
DPL Ichikawa	1.3490	149
Atsugi Minami L.C. B	1.3489	150
Landport Atsugi Kanada	1.3487	151
Landport Ome III	1.3480	152
DPL Tsukuba Ami I-B	1.3477	153
Kuki D.C.	1.3475	154
Prologis Park Tokyo Ota	1.3474	155
Logiport Sagamihara	1.3451	156
DPL Saitama Kamisato A	1.3448	157
Tokyo Rail Gate EAST	1.3430	158
DPL Gunma Fujioka	1.3430	159
Prologis Park Zama 2	1.3422	160
DPL Koto Fukagawa	1.3404	161
Logicross Atsugi II	1.3368	162
Landport Kawagoe	1.3345	163
SG Realty Kashiwa K	1.3326	164
LOGIBASE Fujisawa	1.3322	165
DPL Yokohama Daikoku	1.3302	166
Landport Kashiwa-Shonan I	1.3292	167
Prologis Park Kitamoto	1.3268	168
Landport Tama	1.3267	169
Sagawa Express Itako Office	1.3254	170
Nakano Shokai Tatsumi Center	1.3238	171
Prologis Urban Tokyo Adachi 1	1.3225	172
Landport Shinonome / Yasuda Warehouse	1.3223	173
DPL Urawa Misono	1.3220	174
Landport Atsugi Aikawa Machi	1.3179	175
Tsukuba Chuo	1.3136	176
Landport Narashino	1.3107	177
Prologis Park Narita 1-B	1.3067	178
Logicross Narashino	1.3001	179
Atsugi Minami L.C. A	1.2946	180
Landport Ageo II	1.2912	181
Prologis Park Koga 4	1.2868	182
Narita D.C.	1.2867	183
Prologis Park Narita 3	1.2863	184
Landport Ome Ⅱ	1.2856	185
Goodman Business Park South	1.2815	186
Prologis Park Jouso	1.2769	187
Moriya D.C.	1.2765	188
Prologis Park Yachiyo 1	1.2762	189
Prologis Park Funabashi 5	1.2736	190
Noda D.C.	1.2727	191
DPL Okegawa	1.2709	192
DPL Maebashi	1.2663	193
Goodman Business Park North	1.2646	194
Prologis Park Narita 1-D	1.2629	195
Goodman Business Park East Gate	1.2604	196
MFLP Yachiyo Katsutadai	1.2445	197
DPL Utsunomiya	1.2177	198
Prologis Park Chiba New Town	1.2010	199
Goodman Business Park West	1.1863	200
Landport Kashiwa-Shonan II	1.1640	201

Note that D.C. and L.C. means Distribution Center and Logistics Center, respectively.

REFERENCES

1) Balcik, B. and Beamon, B. M. : Facility location in humanitarian relief, *International Journal of Logistics: Research and Applications*, Vol. 11, pp.101-121, 2008.
2) Balaji, M., Santhanakrishnan, S. and Dinesh., S. N. : An Application of Analytic Hierarchy Process in Vehicle Routing Problem, *Periodica Polytechnica Transportation Engineering*, Vol. 47, pp.196-205, 2018.
3) Badalpura, M. and Nurbakhsh, E. : An application of WASPAS method in risk qualitative analysis: a case study of a road construction project in Iran, *International Journal of Construction Management*, Vol. 21, p.1-9, 2019.
4) Caunhye, A. M., Zhang, Y. D., Li, M. Z. and Nie, X. F. : A location-routing model for prepositioning and distributing emergences, *Transportation Research Part E: Logistics and Transportation Review*, Vol.90, pp.161-176, 2016.
5) Chakraborty, S. and Zavadskas, E. K. : Applications of WASPAS Method in Manufacturing Decision Making, *Informatica*, Vol. 25, pp.1-20, 2014.
6) Chakraborty, S., Zavadskas, E. K. and Antucheviciene, J. :Applications of waspas method as a multi-criteria decision-making tool, *Economic computation and economic cybernetics studies and research /Academy of Economic Studies*, Vol. 49, pp.5-22, 2015.
7) Fan, J. and Huang, G. W. : Evaluation of Flood Risk Management in Japan through a Recent Case, *sustainability*, Vol.12, pp.2-17, 2020.
8) Guo, Y. F. and Matsuda, T. : Study on the multi-criteria location decision of wide-area distribution centers in pre-disaster: Case of an earthquake in the Kanto district, *Takushoku University*, 2023.
9) Li, H., Zhang, B. and Ge, X. Y. : Modelling Emergency Logistics Location-Allocation Problem with Uncertain Parameters, *Systems*, Vol.10, pp.1-17, 2022.
10) Loree, N. and Aros-Vera, F. : Points of distribution location and inventory management model for Post-Disaster Humanitarian Logistics, *Transportation Research Part E Logistics and Transportation Review*, Vol. 116, pp.1-24, 2018.
11) Lukic, R., Dragana, V. K., Slavica, A. and Milan, G. : Application of WASPAS method in the evaluation of efficiency of agricultural enterprises in Serbia, *Ekonomika Poljoprivrede*, Vol. 68, pp. 375-388, 2021.
12) Mittal, R. and Obaid, A. : Sustainable Warehouse Location Selection in Humanitarian Supply Chain: Multi-Criteria Decision-Making Approach, *International Journal of Mathematical, Engineering and Management Sciences*, Vol. 8, No. 2, pp.316-335, 2023.
13) Nong, T. N. M. : A hybrid model for distribution center location selection. *Asian Journal of Shipping and Logistics*. Vol. 38, pp.40-49, 2021.
14) Paul, J. A. and Donald, L. M. : Location and capacity allocations decisions to mitigate the impacts of unexpected disasters, *European Journal of Operational Research*, Vol. 251, pp. 252-263, 2016.
15) Paul, J. A. and Hariharan, G. : Location-allocation planning of stockpiles for effective disaster mitigation. *Annals of Operations Research*, Vol.196. pp.469-49, 2012.
16) Polat, T. K. : An Application of Analytic Hierarchy Process and Fuzzy Analytic Hierarchy Process to The Case Type Selection Problem, *Academic Perspective Procedia* ,Vol.1, pp.1179-1188, 2018.
17) Rimadeni, Y., Nasrullah, N., Afdhal, A., Pamudi, B. F., Munazar, M., Arnisam, A., Surya, E. : Disaster Logistics Management as an Educational Foundation for Disaster Logistics Managers, *Jurnal Serambi Ilmu*, Vol. 22, No. 1, pp.33-49, 2021.
18) Rautela, P., Jugran, R., Kundalia, S., Joshi, G. G. C. and Khanduri, S. : Disaster Risk Reduction Lessons from February 7, 2021 Flash Flood in Uttarakhand Province of India, *Journal of Disaster and Emergency Research*,Vol. 5, pp.57-69, 2021.
19) Rawls, G. G. and Turnquist, M. A. : Pre-positioning of emergency supplies for disaster response, *Transportation Research Part B Methodological*, Vol.44, pp.521-534, 2010.
20) Rudnik, K., Bocewicz, G., Landwojtowicz, A. K. and Czabak-Gorska, I. D. : Ordered fuzzy WASPAS method for selection of improvement projects, *Expert Systems with Applications*, Vol.169, No.114471, 2020.
21) Suzuki, Y. and Kim, Y. :The Great East Japan earthquake in 2011; toward sustainable mental health care system, *Epidemiology and Psychiatric Sciences*, Vol. 21, pp.7-11, 2012.
22) Tofighi, S., Torabi , S. A. and Mansouri, A. : Humanitarian logistics network design under mixed uncertainty. *European Journal of Operational Research*, Vol.250 (1), pp.239-250, 2016.
23) Tuhamy, E., Elatif, M. M. A. and El-Bakry, H. M. : Optimal Routing Selection Using Analytical Hierarchy Process. *International Journal of Advancements in Computing Technology*. Vol. 8, pp.44-5, 2016.
24) Utami, M. A. and Ruskan, E. L. : The Determination of Reward and Punishment Using WASPAS Method, *Advances in Intelligent Systems Research*, Vol.172, 2019.
25) Wan, S. P., Chen, Z. H. and Dong, J. Y. : Bi-objective trapezoidal fuzzy mixed integer linear program-based distribution center location decision for large-scale emergencies. *Applied Soft Computing*, Vol.110, No.107757, 2021.
26) Wang, H. C. and Ma, X. Y. : Research on Multiobjective Location of Urban Emergency Logistics under Major Emergencies, *Mathematical Problems in Engineering*, Vol.2021, pp.1-12, 2021.